Composite Materials
The "Wet" Navy
Ships and Major Ship's Components

Smaller projects under NAVSEA 05N's Engineering To Reduce Maintenance and Capital Investment for Labor

November 5, 2003

Jeff Goldring

NAVSEA 05M3

OSPREY (MHC 51) Class Minehunter

Length:	57.2 meters (187 feet, 10 inches)
Beam:	11.0 meters (35 feet, 11 inches)
Draft:	2.9 meters (9 feet, 4 inches)
Displacement:	895 metric tons
Propulsion:	two 800 hp amagnetic diesel engines with variable fluid drives turning two cycloidal propellers
Accommodations:	5 officers; 4 CPO; 42 enlisted

Construction Particulars

All glass reinforcement for primary structure is E glass. Spun woven roving of 1400 grams per square meter is used for the hull, transverse bulkheads, and decks. The spun woven roving is a fabric with the weft direction reinforcement consisting of rovings that have been "tufted." This treatment, which gives the fabric a fuzzy appearance, improves the interlaminar shear strength over traditional woven rovings. The superstructure is constructed of a "Rovimat" material consisting of a chopped strand mat stitched to a woven roving. Stitching of the two fabrics was chosen to improve performance with the semi-automated resin impregnator (which is used during the lamination process). The total weight of the Rovimat is 1200 grams per square meter (400 g/m^2 mat + 800 g/m^2 woven roving).

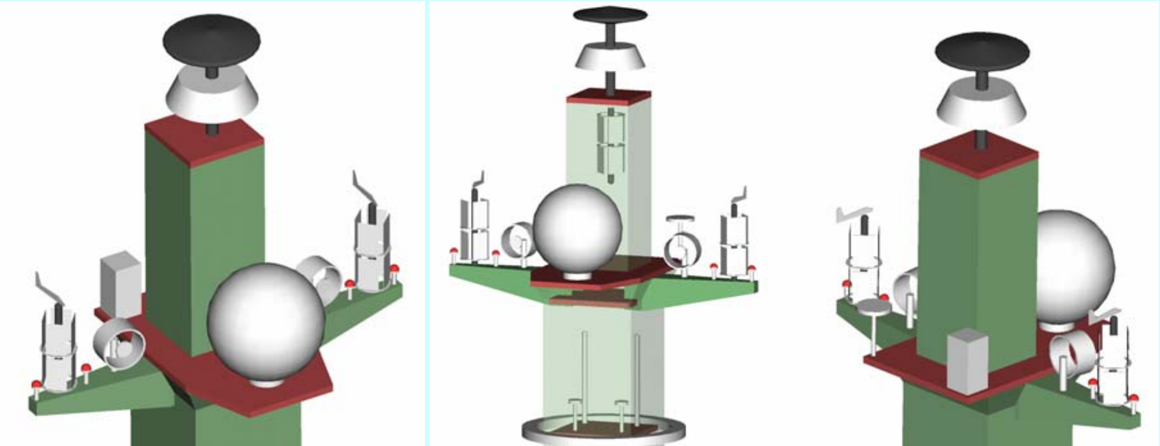
The resin is a high grade toughened isophthalic marine polyester resin. It is specially formulated for toughness under shock loads and to meet the necessary fabrication requirements. The resin does not have brittle fracture characteristics of normal polyester resins, which gives it excellent performance under underwater explosive loads. Combined with spun woven roving, the laminate provides superior shock and impact resistance. The resin formulation has been optimized for improved producibility. Significant is the long gel time (up to four hours) with low exotherm and a long extended delay time to produce a primary bond. [1-32]

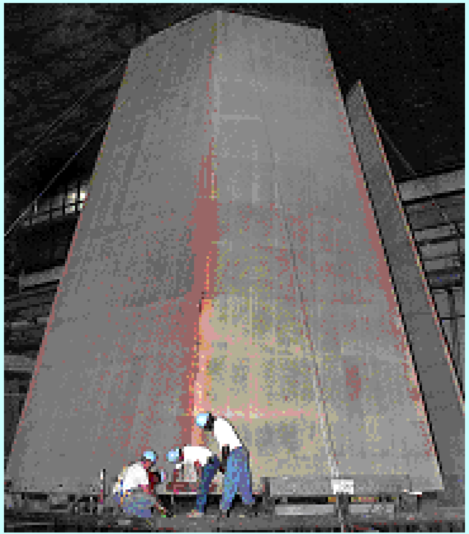
Advanced Enclosed Mast / Sensors

USS Arthur W. Radford (DD 968) AEM/S
93' high, hexagonal structure, 35' in diameter

Advanced Enclosed Mast System
for LPD 17 Class Ships

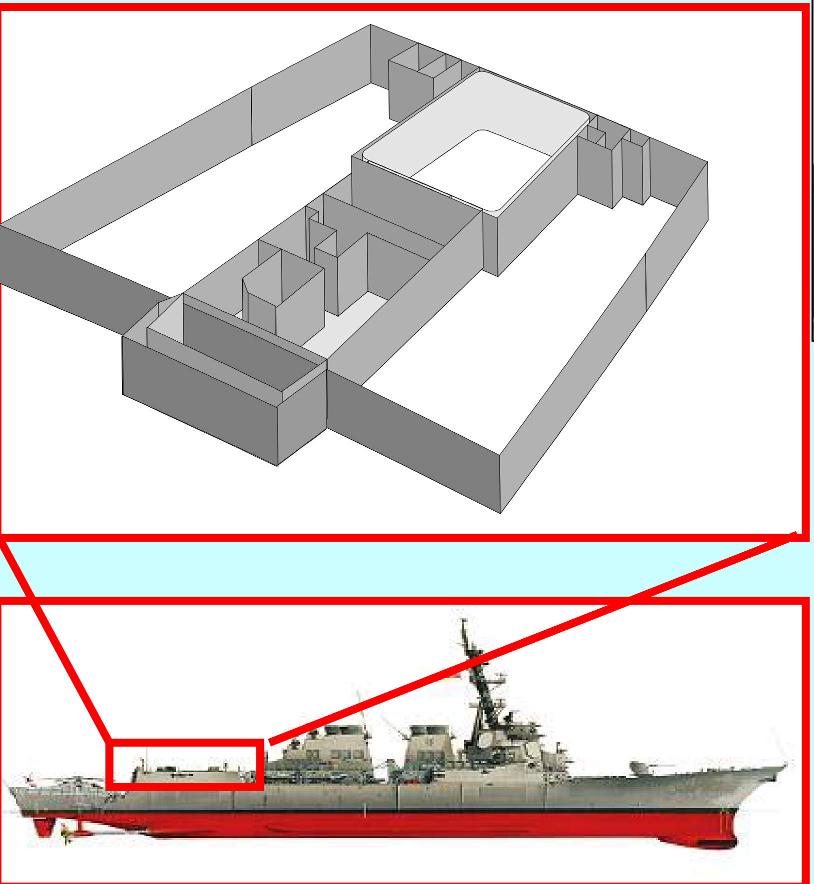
Proposed CVN Mast

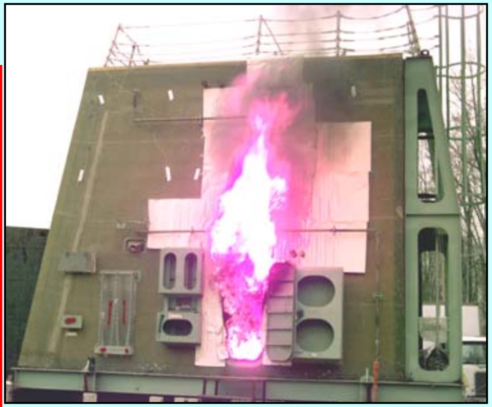




CURRENT MAJOR NAVY COMPOSITES EFFORTS

- COMPOSITE HELO HANGAR FOR DDG 51 CLASS (ONR)
  - DESIGN AND COMPONENT TESTING COMPLETE
  - APPROVED FOR INSTALLATION
  - PROGRAM OFFICE DEEMED IT HIGH RISK AND HIGH COST
  - WILL NOT LIKELY BE BUILT





Composite Helicopter Hanger First Article Door (above) and Operational Test Jig (below) [Seemann Composites]

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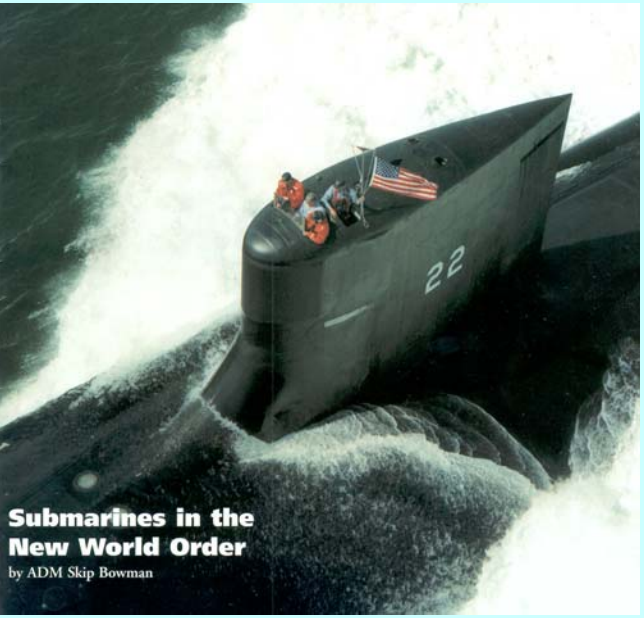
NAVAL SEA SYSTEMS COMMAND

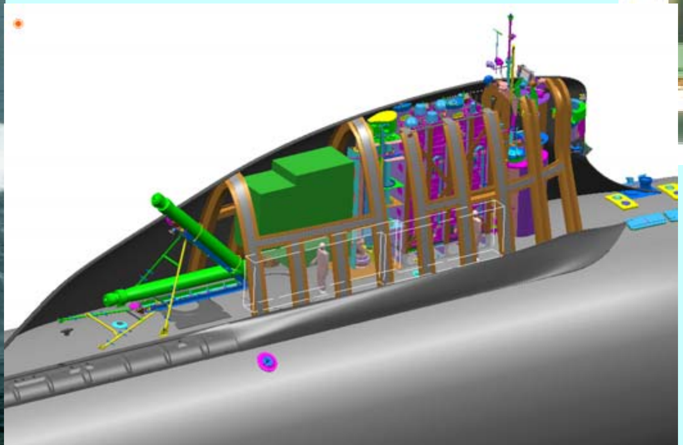
CURRENT SUBMARINE COMPOSITES EFFORTS

JDMAG
Joint Depot Maintenance Activities Group
Joint Solutions For Depot Maintenance



Current Steel SEAWOLF Class Sail

VIRGINIA Class Composite Advanced Sail Concept



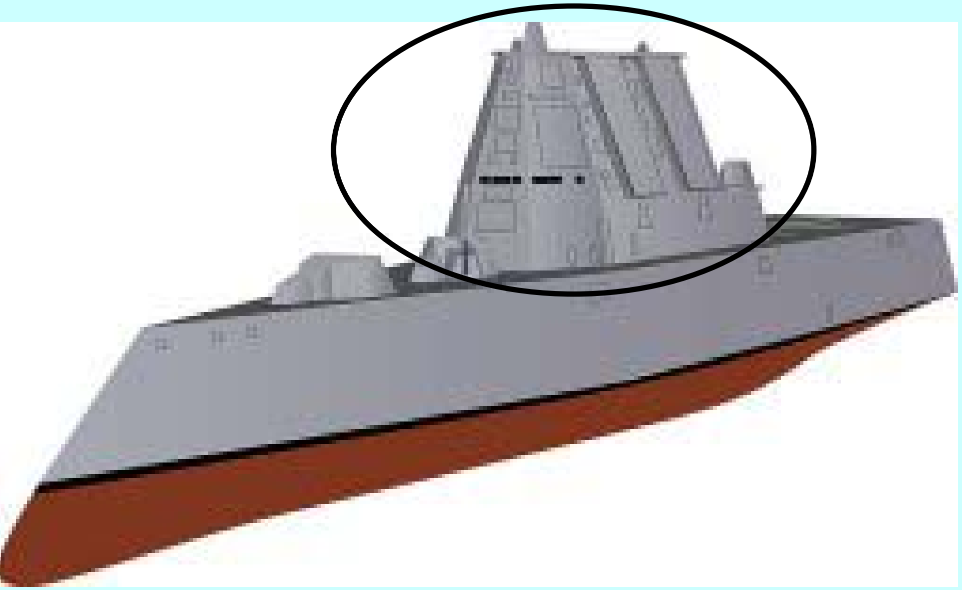
Composite Submarine Bow Dome Produced by Goodrich Composites

NEW SHIPS DESIGNS COMPOSITES EFFORTS

DD(X) Composite Deck House

Possible Balsa Carbon Sandwich

Bonded to steel deck (no bolts)



Raytheon Team

Littoral Combat Ship (LCS)

All Composite Construction

COMPOSITE DECK GRATING

TASK: REPLACE STEEL DECK GRATING WITH GRP (MODAR) ON CVN CATWALK AND IN WELL-DECK OVERHEAD ON L-SHIPS.

METRICS:

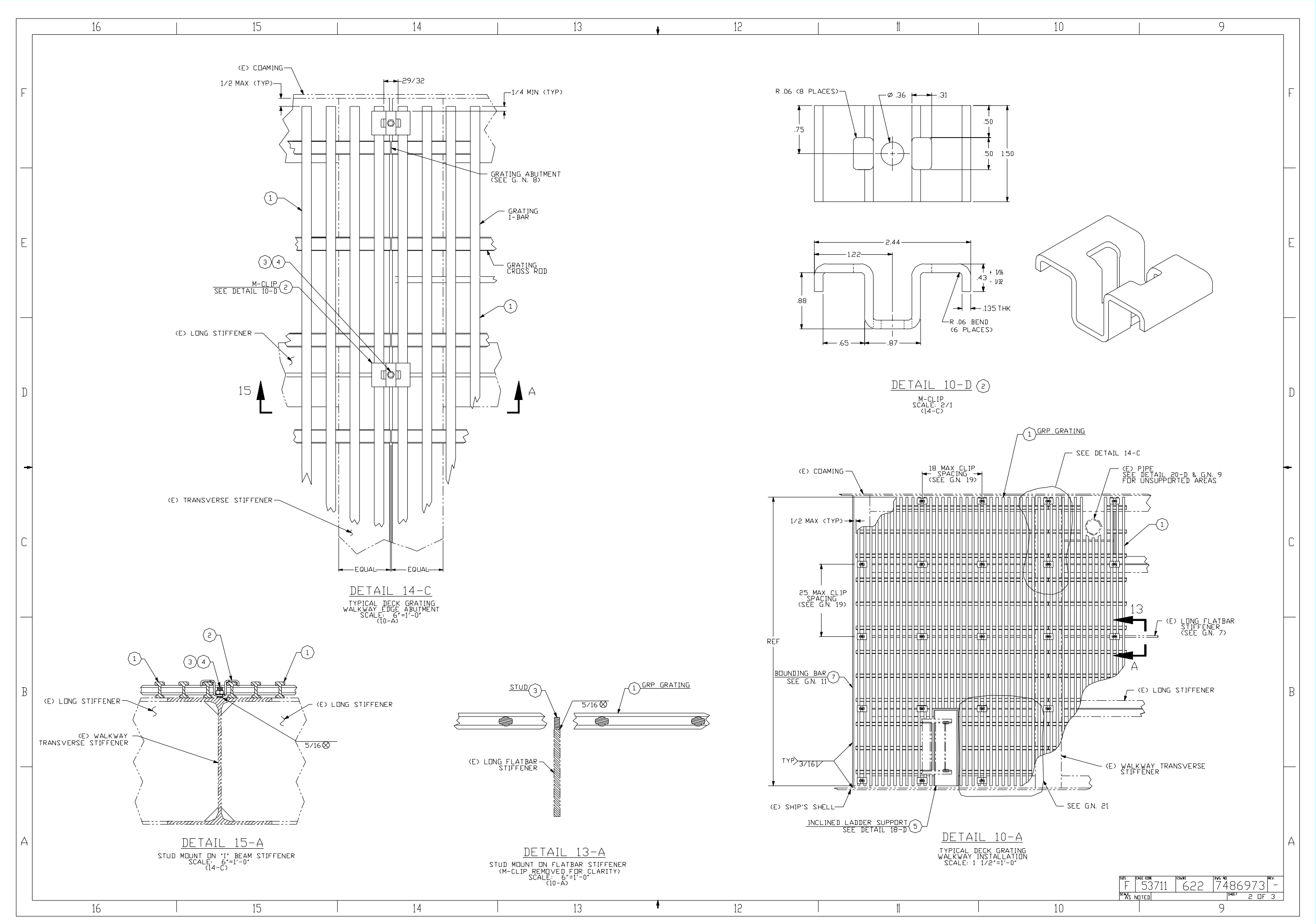
NUMBER OF SHIPS: ONE LSD, TWO COMPLETE CVN
ALL CV / CVN CURRENTLY INSTALLING

COST AVOIDANCE: $23M, ALL CVN, 20-YEAR PERIOD.
$22M, ALL L-SHIP, 20-YEAR PERIOD.
$1.9M USS ABRAHAM LINCOLN (CVN-72) [PAC] - CI-LABOR.
$1.9M USS THEODORE ROOSEVELT (CVN-71) [LANT] - AIRLANT.
INSTALL SAVINGS ≈ $39K (LSD) & $174K (CVN).

MAN-YEAR LABOR AVOIDANCE: 0.55 MAN-YEARS/YEAR ON LSD.
1.92 MAN-YEAR/YEAR (CVN).
≈ 29 MAN-YEAR/YEAR FLEETWIDE.

COMPOSITE DECK GRATING

NAVSEA DRAWING 803-6983499 FOR DECK GRATING INSTALL ON SURFACE SHIPS (LSD & CVN).



COMPOSITE DECK GRATING

- DRAWING AT PORTSMOUTH FOR DISTRIBUTION.
  - ESTABLISH SOURCES FOR GRATING/CLIPS (QPL).
  - ADD GRATING/CLIPS TO STOCK SYSTEM (NAVICP).

PROBLEM - SOME GRATES MADE WITH UNAPPROVED MATERIAL HAVE BEEN INSTALLED.

USS COMSTOCK (LSD 45)
WELLDECK

COMPOSITE VENT SCREEN

TASK: REPLACE STEEL VENT SCREENS WITH GRP (MODAR). IMPROVE MOUNTING IN COAMING TO USE CORROSION-RESISTANT MATERIALS.

METRICS:

NUMBER OF SHIPS: 2 COMPLETE & 3 PARTIAL, CI-LABOR.
FLEET IS INSTALLING AS REQUIRED.

COST AVOIDANCE: $165M, ALL SHIPS, 20-YEAR PERIOD.
$450K, USS ARTHUR W. RADFORD (DD-968) [LANT] - CI-LABOR.
$599K, USS STOUT (DDG-55) [LANT] EIGHT SCREENS - CI-LABOR.
$2.7M USS ABRAHAM LINCOLN (CVN-72) [PAC]- AIRPAC/CI-LABOR

MAN-YEAR/YEAR LABOR AVOIDANCE: 52.9 MAN-YEARS/YEAR ON ALL SHIPS.
0.13 MAN-YEAR/YEAR (DD-968).
0.88 MAN-YEAR/YEAR (DDG-51).
1.17 MAN-YEAR/YEAR (CVN-72).

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COMPOSITE VENT SCREEN

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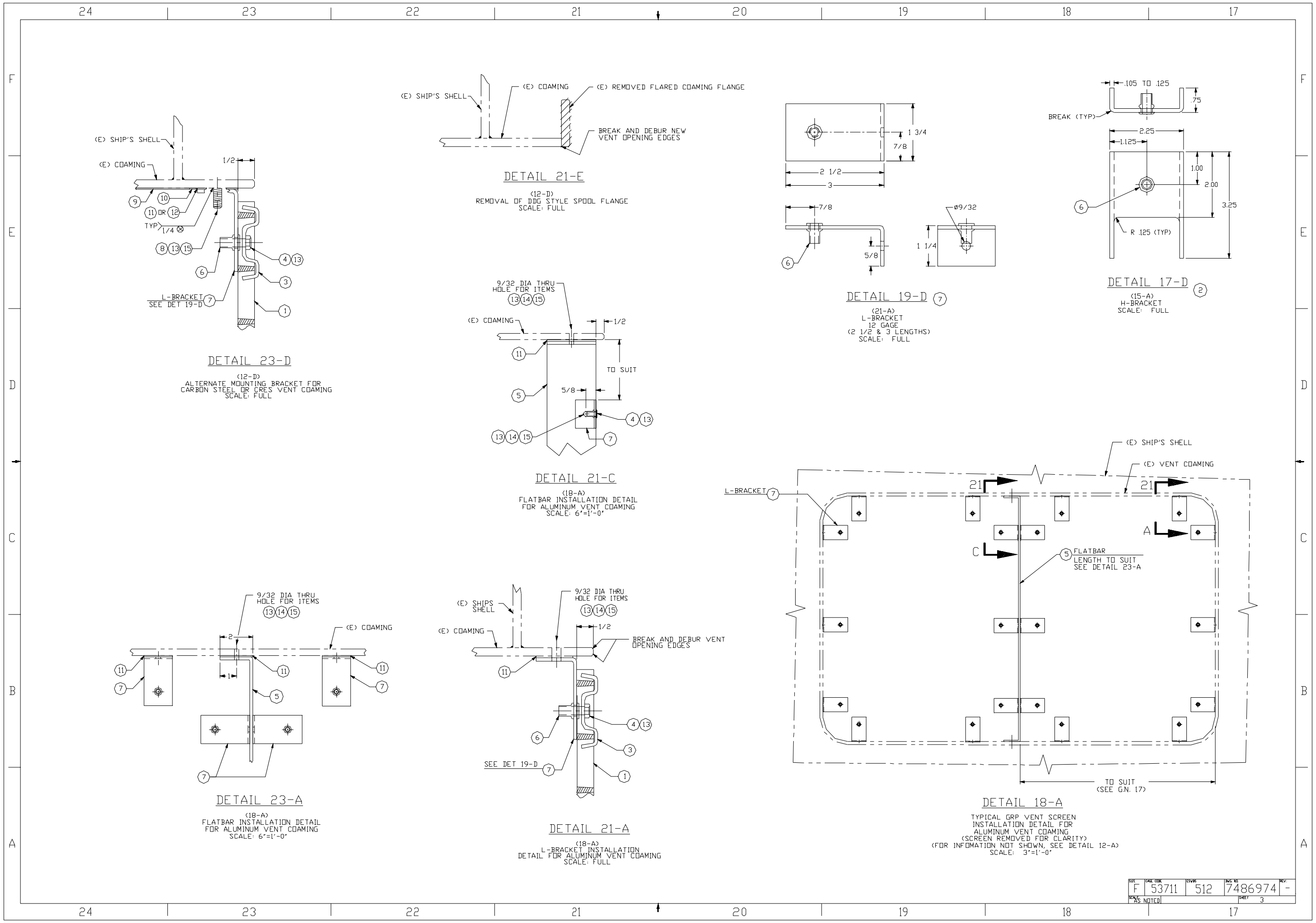
Joint Solutions For Depot Maintenance



NAVSEA DRAWING 6983500

PUT SCREENS AND MOUNTING INTO STOCK SYSTEM

SUPPLY NAVICP WITH INITIAL STOCK

PROBLEM – SOME SCREENS MADE WITH UNAPPROVED MATERIAL BEING INSTALLED BY FLEET

COMPOSITE VENT SCREEN INSTALLATION ON DDG-55

“BEFORE” CONDITION, CORRODED “PICTURE FRAME” FLANGE ON USS STOUT (DDG-55)

“AFTER” CONDITION, NEW SCREENS, CLIPS, AND GROUND COAMING.

COMPOSITE ELECTRICAL BOXES

TASK: REPLACE METALLIC ELECTRICAL BOXES THAT CORRODE OR CAUSE CORROSION OF THE SHIP STRUCTURE WITH COMPOSITE BOXES AND STAINLESS STEEL MOUNTING HARDWARE.

METRICS:

NUMBER OF SHIPS: 5 PARTIAL (ERM/CIL),
LSD 45 & 47 COMPLETE STERN GATE CONTROLLER
CVN 73 SHOWCASE 94 BOXES INSTALLED 6/03

COST AVOIDANCE: ERM/CIL INSTALL: $59K (LIFE-CYCLE).
FLEET SAVINGS (PROJECTED): $64.5M

MAN-YEAR LABOR AVOIDANCE: ERM-7 INSTALL: 0.74 manyear
FLEET SAVINGS: 36 manyear/year
(PROJECTED)

ELECTRICAL BOXES

COMPOSITE BOX PERFORMANCE REQUIREMENTS:

TEST	ISSUE	REQUIREMENT
MIL-S-901	Shock	Grade A, Class 1, No failure
MIL-STD-167-1	Vibration	2-hour test, No failure
MIL-STD-1344	Impact / Random Drop	Six times, 4 ft drop, No failure
MIL-STD-461/1310	EMI / EMP	2 Frequency ranges
MIL-STD-810	Salt Fog	96 hr wet/dry, No corrosion
MIL-STD-810	High and Low Temperature	-28 F to 149 F, 3 days, Function, No cracking or sagging
MIL-STD-108	Splash proof, Watertight	Hose spray, 5 gpm. No liquid penetration
MIL-STD-810	Solar Radiation	56, 24 hr cycles, no color change
ASTM E 162	Flame Spread / Dripping	25, self extinguish, no drip
ASTM E 1354	Smoke / Heat Release	Cone 25, 50, 75 kW/m^2
ASTM E 662	Smoke Density	Smoke < 200
NAVSEA	Fire Containment Test	2.5 KW for 3.5 minutes

COMPOSITE ELECTRICAL BOXES

- BOX INSTALLED ON USS BARRY (DDG-52).

BEFORE: NOTE CORROSION OF MOUNTING PANEL.

ALPHA TEST VERSION: BASE PLATE PRESERVED WITH EURONAVY 301 & SILICONE ALKYD.

COMPOSITE ELECTRICAL BOXES

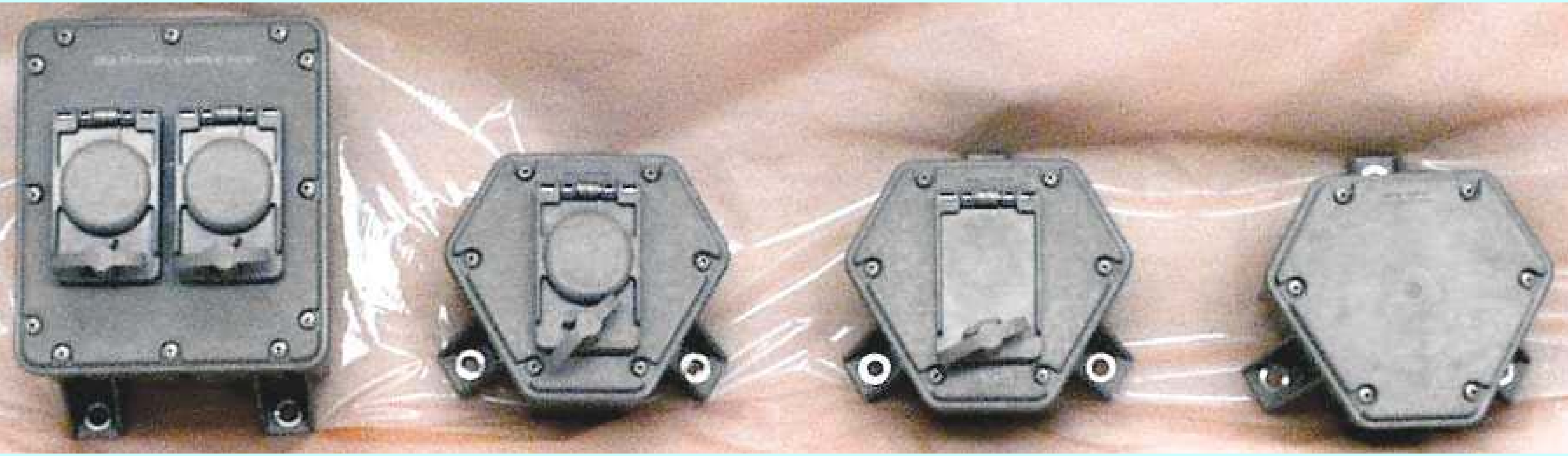
- **BOX INSTALL ON USS VELLA GULF (CG-72).**

BEFORE: NOTE CORROSION OF MOUNTING PANEL.

ALPHA TEST INSTALL: COATED SUBSTRATE, COMPOSITE BOXES.

ELECTRICAL BOXES

BETA VERSION FAMILY FROM GLENAIR

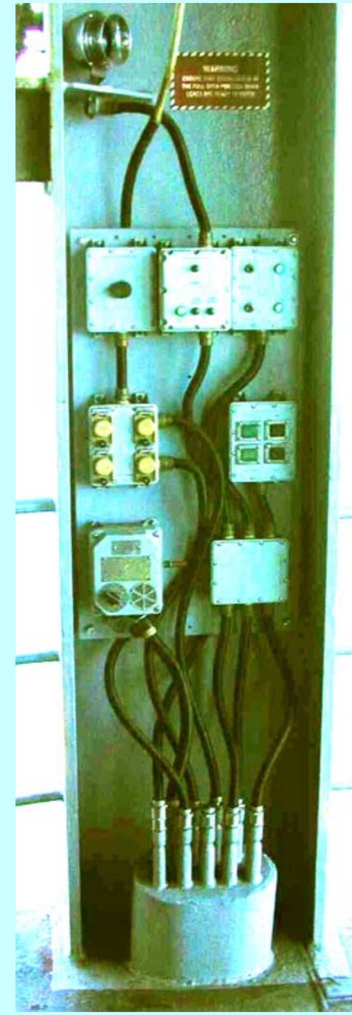


SOUND POWERED PHONES **125VAC** **JUNCTION**

- **NEW LATCHES**
- **NEW SEALS**
- **BEEFED UP FEET**
- **ALL 304/316 HARDWARE**
- **PASSED REQ'D TESTS**

ELECTRICAL BOXES

STERN GATE CONTROLLER
ON USS COMSTOCK (LSD-45).



AFTER 1 YEAR

WITH PEEK CONDUIT.

BEFORE: CORROSION OF BOXES.

COMPLETELY NON FUNCTIONAL – SHOCK HAZARD

COMPOSITE ROPEGUARDS & FAIRWATERS

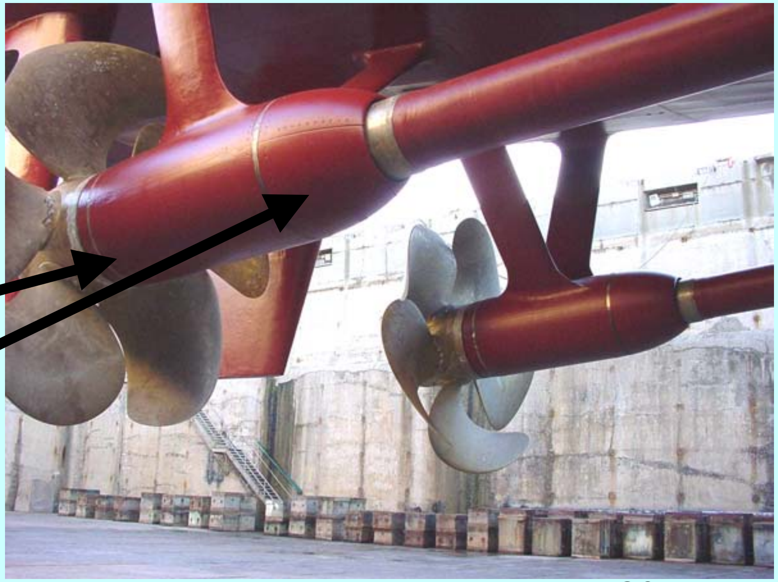
TASK: REPLACE METALLIC ROPEGUARDS & FAIRWATERS WITH GRP.

METRICS:

NUMBER OF SHIPS: SIX COMPLETE
- USS RUSSELL (DDG-59) [PAC]
- USS HIGGINS (DDG-76) [PAC]
- USS DWIGHT D. EISENHOWER (CVN-69) [LANT]
- USS NIMITZ (CVN-68) [PAC]
- USS THEODORE ROOSEVELT (CVN-71) [LANT]
- USS PORT ROYAL (CG-73) [PAC]
- USS ENTERPRISE (CVN-65) [LANT]
- USS CARL VINSON (CVN-70) in progress
- USS ABRAHAM LINCOLN (CVN-72) [PAC]

ROPEGUARDS & FAIRWATERS

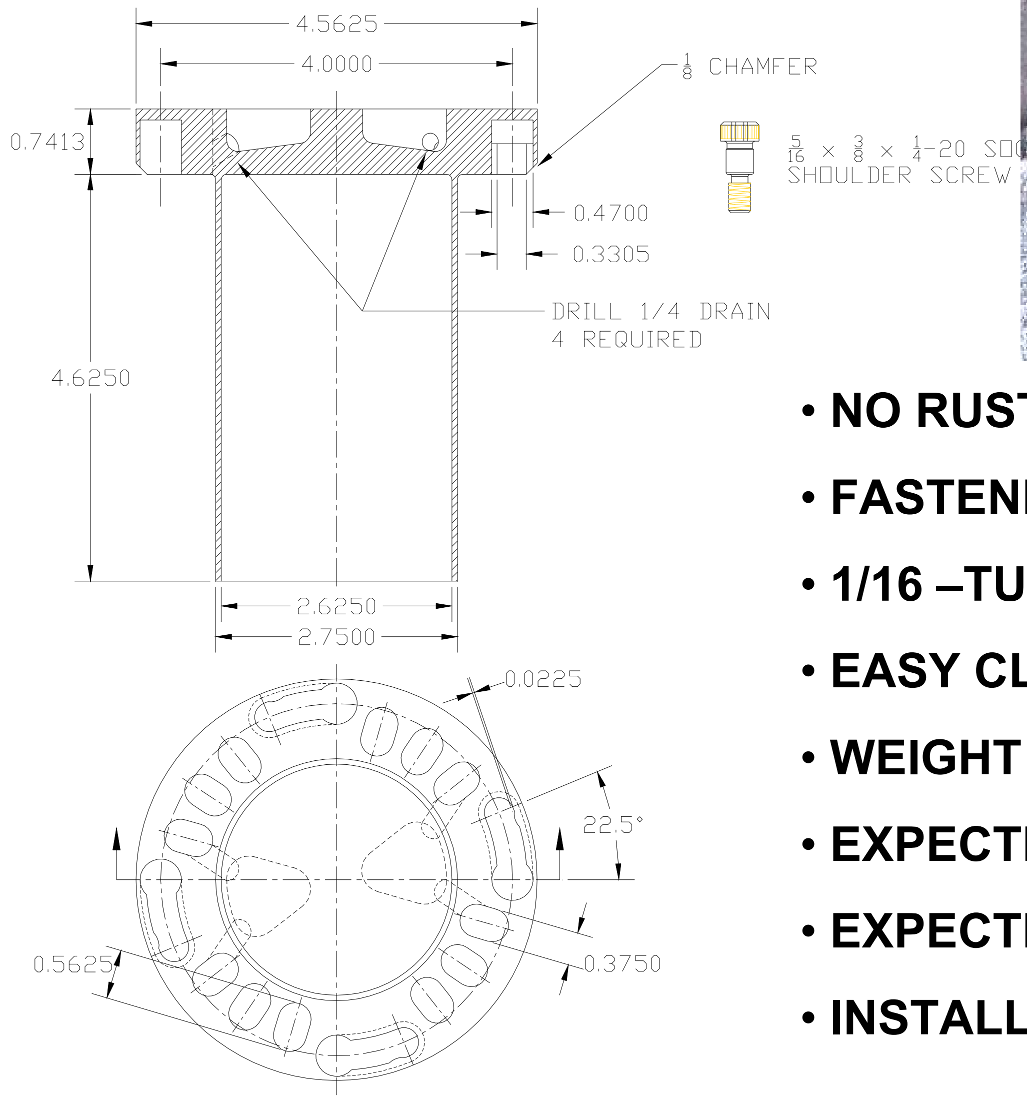
- COMPOSITE FAIRWATERS PERFORMING WELL.
- CVN-65 INSTALL AUGUST 02.
- WORKED WITH PMS-312 TO DEVELOP DRAWINGS FOR CVN-68 CLASS ROPEGUARDS AND FAIRWATERS.
  - COMPLETED DRAWINGS.
  - CVN CONFIGURATION CONTROL BOARD ACCEPTED GRP CONCEPT, NSWCCD GAVE ADDITIONAL METRICS TO PMS-312.
  - DDG-51 CLASS ACCEPTED GRP
    - IN LIEU OF CuNi WELDED INSTALL
    - ALLOWS AFLOAT REMOVAL



ROPEGUARD

FAIRWATER

OSITE DECK DRAIN SCREEN IN MANUFACTURED BY SPARTA INC.



- NO RUST / CORROSION
- FASTENERS PERMINANTLY INSTALLED
- 1/16 –TURN OPENING – NO TOOLS
- EASY CLEANING
- WEIGHT SAVINGS
- EXPECTED COST AVOIDANCE
- EXPECTED MAINTENANCE AVOIDANCE
- INSTALLATION KIT PROVIDED

PUMPS & PUMP PARTS

TASK: REPLACE METALLIC PUMPS AND PUMP PARTS WITH LOW-MAINTENANCE GRP PRODUCTS.

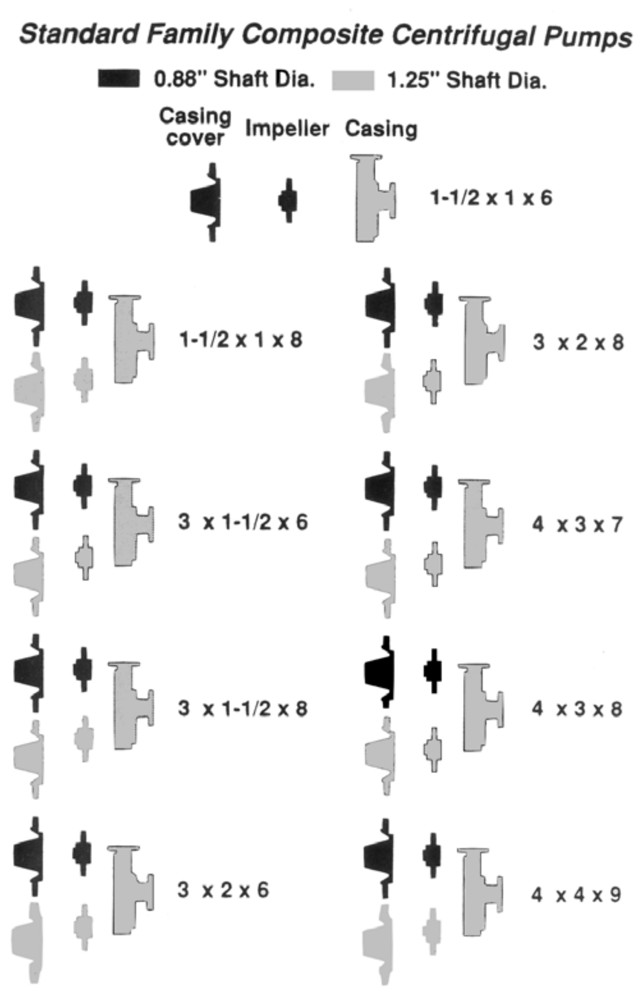
METRICS:

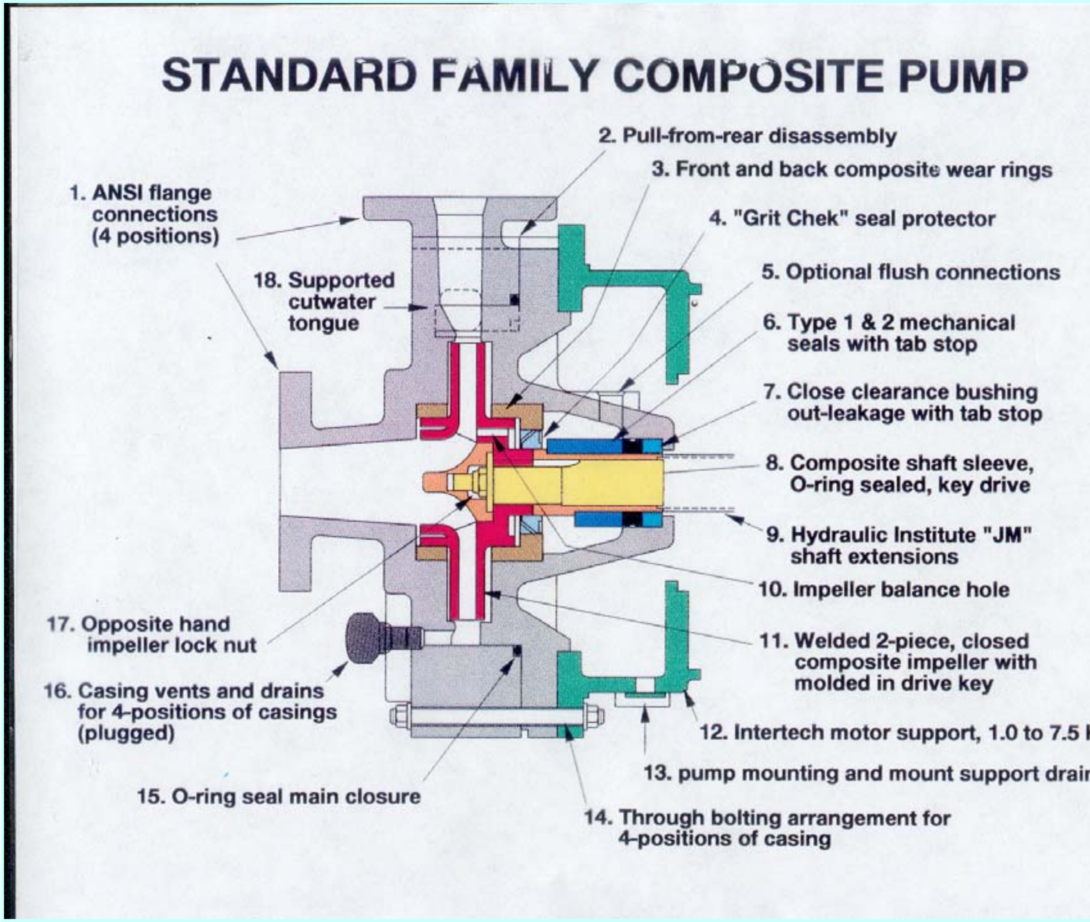
NUMBER OF SHIPS: NO COMPLETE SHIP SETS.
USS CARTER HALL (LSD-50) [LANT] FOUR DIESEL COOLING.
USS YORKTOWN (CG-48) [LANT] TWO 3X2X6.
USS LEYTE GULF (CG-55) [LANT] ONE 3X2X6.
USS JOHN C. STENNIS (CVN-74) [PAC] TWO BRINE.

COST AVOIDANCE: CG-47 CLASS, THREE-PUMP SET OF AEGIS COOLING PUMPS SAVE $87K IN DIRECT INSTALL COSTS.
$3.7M OVER 20-years SAVINGS, ALL CG-47.
CVN-68-CLASS SHIPS SAVE $118.8K FOR COMPOSITE BRINE PUMP INSTALLATION.
$38.3M IN PREDICTED 30-year SAVINGS (CREI).

MAN-YEAR SAVINGS: 1.06 MAN-YEAR/YEAR ON CG-47 CLASS.
20.1 MAN-YEAR/YEAR FLEETWIDE.

FAMILY OF COMPOSITE PUMPS

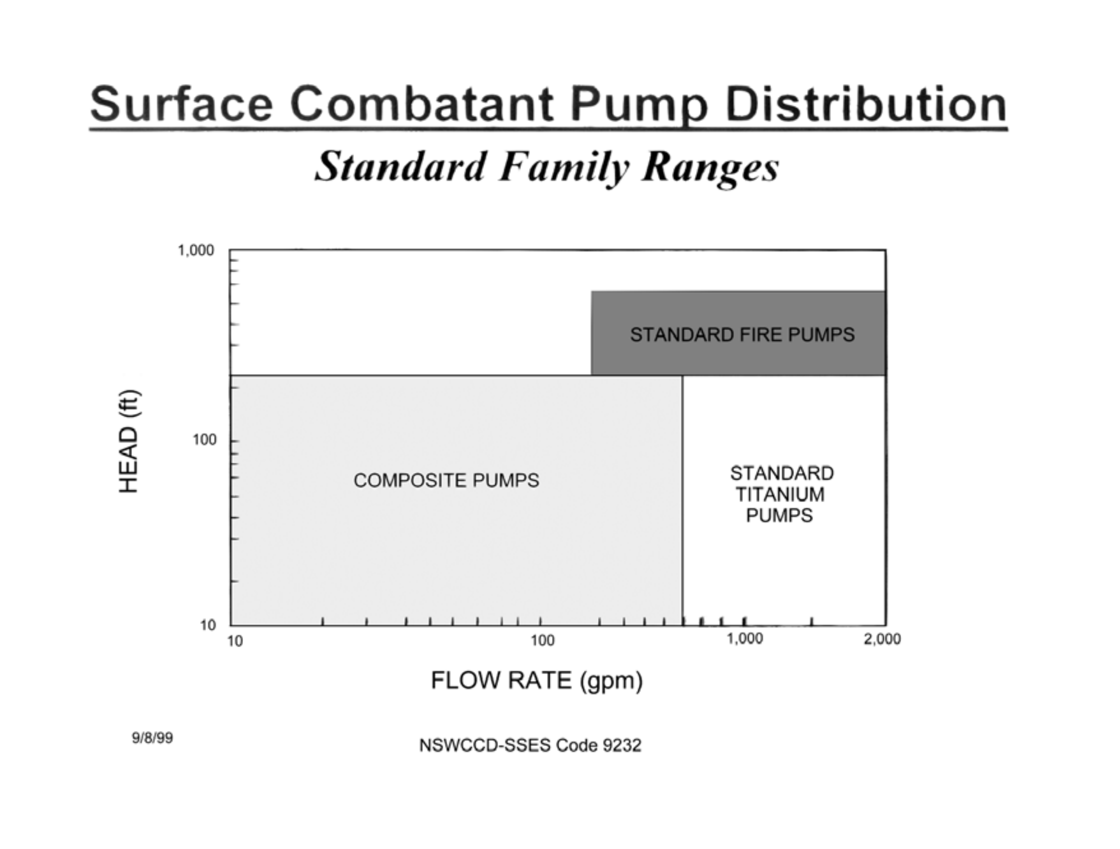




COMPOSITE FAMILY OF PUMPS

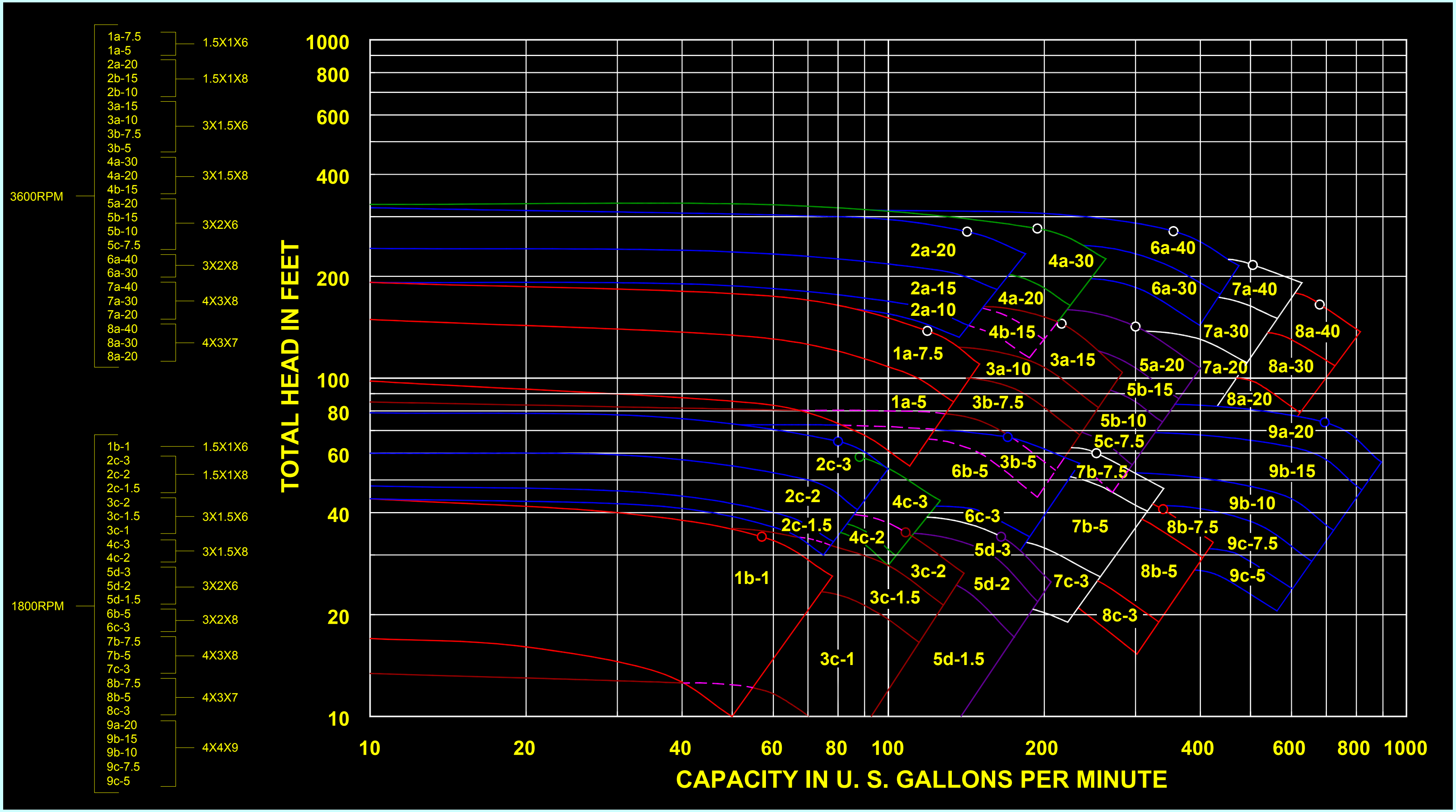
FAMILY COMPONENTS
17 PUMPS IN FAMILY
1 TO 40 HP

DRAIN/VENT PLUG	1
BOX BUSHINGS	2
IMPELLER NUTS	2
MECHANICAL SEALS	2
SHAFT SLEEVES	2
WEARING RINGS	2
CASING RINGS	5
CASINGS	9
MOTOR SUPPORTS	12
CASING COVERS	17
IMPELLERS	17

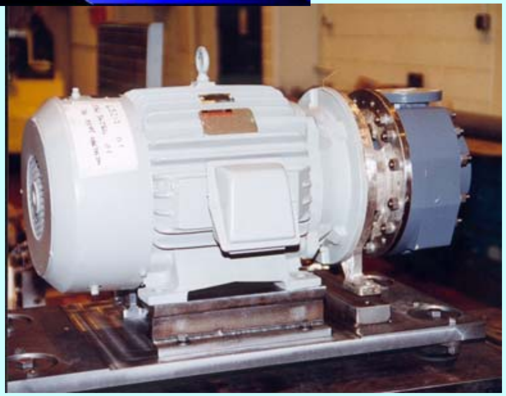


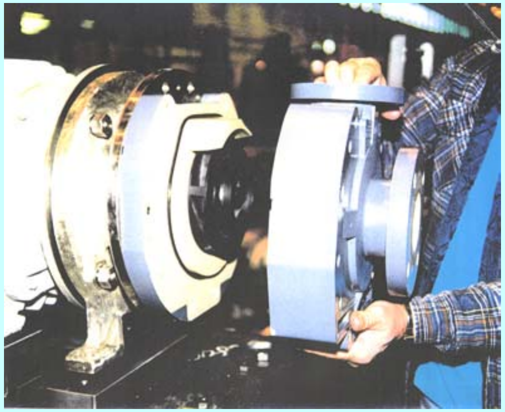
71 REPLACEMENT PARTS

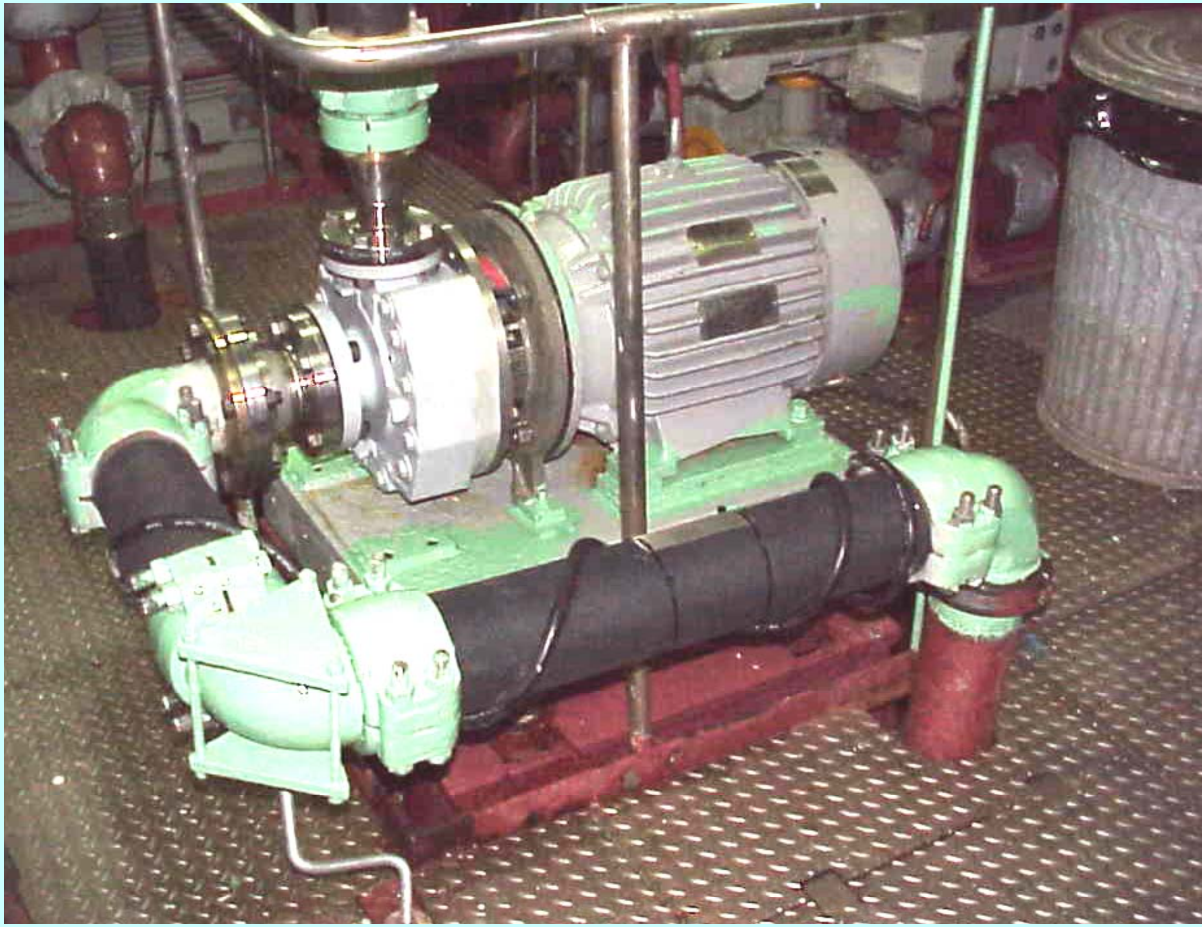
COMPOSITE PUMPS FAMILY HYDRAULICS



COMPOSITE PUMPS







SIZE 5 - 3X2X6 (inlet, outlet, impeller)

1 MAN 1.5 HOURS FOR TOTAL REBUILD

COMPOSITE PUMPS

SUCCESS STORY ON USS YORKTOWN (CG 48)

- 2, 20hp Composite AEGIS Seawater Cooling Pumps Installed 8 Years Ago
- Forward Pump 0 failures 44,000 hours (as of June 03)
  - Opened for evaluation
    - Running to as-new spec
    - No deterioration of any kind
    - Back in service with no new parts
    - 1.5 hours to disassemble and reassemble
      - Requires 2 wrenches and 1 screwdriver
- Aft Pump had 2 failures 38,000 hours
  - same cause - failed motor bearings not discovered till 2nd repair
    - Motor sent out for rebuild
    - Pump repaired in place

AEGIS Seawater Cooling Pump	$ parts for 1 repair	$ labor for 1 repair	$/ship/6-years (actual)	$/ship/30-years (projected)
Metal	18,500	70,100	769,713	3,848,562
Composite	3,400	100	3,700	18,500
Cost Avoidance	15,100	70,000	766,013	3,830,062

COMPOSITE PUMPS

Comparison of Composite vs. Metal In 20-HP AEGIS Seawater Cooling Pump

Flowserve Pump Div.	Composite	Metal	Differential
Purchase Cost	$17,469	$17,982	$513
Weight w/ motor dry	536	750	214
# Pumps on CG-47 Class	2	32	30
# Documented Failures / 6 yrs	2 (in 8 years)	139	N/A
Class Failures Normalized to 34 pumps/6 yrs	34	147.7	113.7
MTBF	4 years (still counting)	1.47 years	2.53+
MTTR	1.23 man-hrs	688 man-hrs	686.7

PUMP & PUMP PARTS

- MHC AUXILIARY SEAWATER COOLING.
  - COMPLETED COMPOSITE UPGRADE.
    - COMPOSITE CASE COATING, IMPELLER AND NEW SPLIT SEAL.
- MTBF METAL 1¼ YR.
- EXPECTED MTBF COMPOSITE 4 YR. (2 YRS SO FAR)

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BRINE PUMPS ON CVN'S

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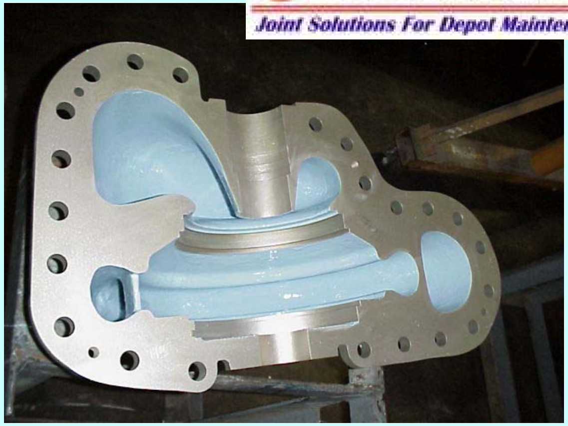
BRINE PUMP INSTALLED

CARVER COMPOSITE IMPELLER



EPOXY COATING ON INSIDE OF PUMP CASING

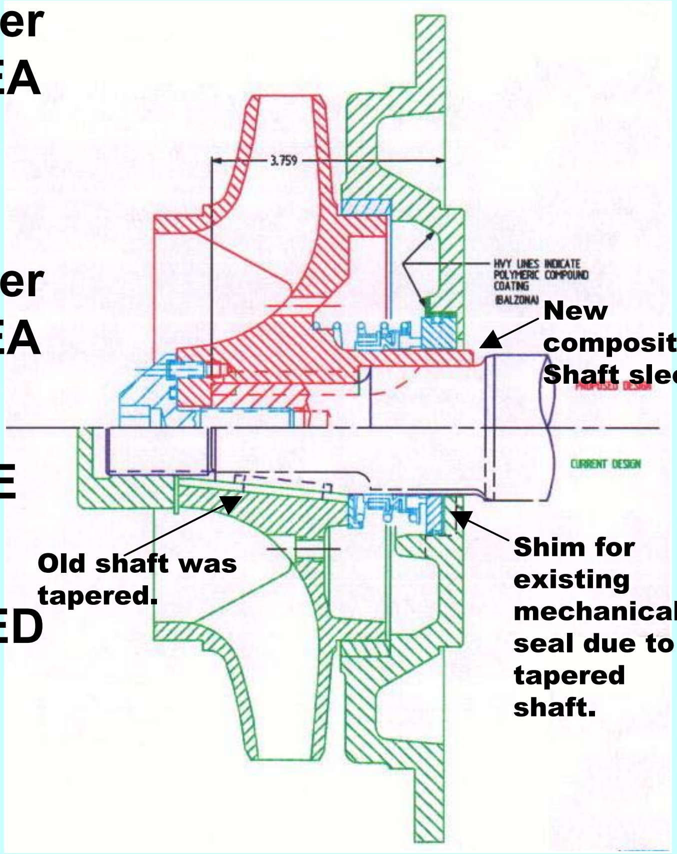
2 BRINE PUMPS (#1 & #3) INSTALLED 31 JAN 02 ON CVN-74 [PAC] OPERATING FLAWLESSLY TO DATE.
BRINE PUMPS #2 & #4 HAD METAL IMPELLERS REPLACED JAN 03.

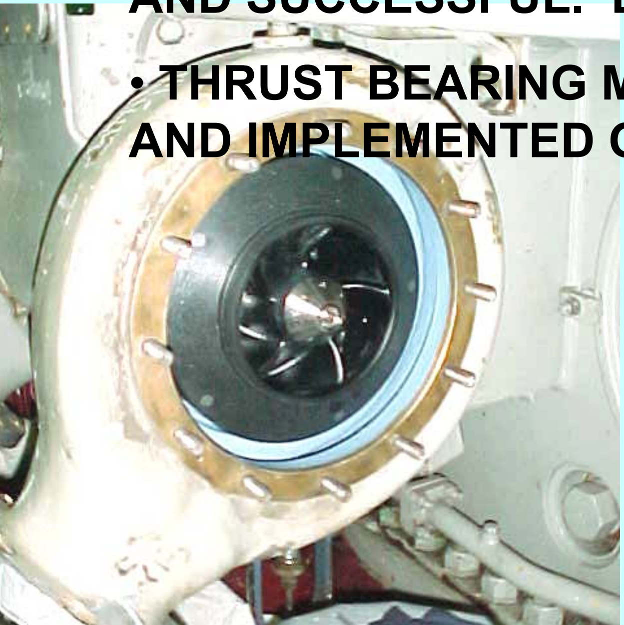
SHAFT SLEVE

WEAR RING

ATTACHED DIESEL PUMP ASSEMBLY

- **AER 13/01 FOR LSD-41 CLASS "Modify Main Propulsion Diesel Engine Attached Jacket Water And Seawater Pumps" APPROVED VIA NAVSEA ltr Ser 470/488 DATED 6 JUL 01.**
- **AER 14/01 FOR LSD-49 CLASS "Modify Main Propulsion Diesel Engine Attached Jacket Water And Seawater Pumps" APPROVED VIA NAVSEA ltr Ser 470/488 DATED 6 JUL 01.**
- **LSD-50 AND LSD-51 PUMP MODS COMPLETE AND SUCCESSFUL. LSD-44 SCHEDULED.**
- **THRUST BEARING MODIFICATION APPROVED AND IMPLEMENTED ON LSD-50.**





<u>Composite mods install:</u>

1. **Composite impeller**
2. **Composite shaft sleeve (existing design has no shaft sleeve)**
3. **Composite wear rings**
4. **Polymeric coating to casing**
5. **New modified shafts (straight vs.tapered)**
   No mech. seal shim req'd.
6. **New mechanical seals**

COMPOSITE VALVES & VALVE PARTS

TASK: REPLACE METALLIC VALVES & VALVE PARTS WITH LOW-MAINTENANCE GRP PRODUCTS.

METRICS:

NUMBER OF SHIPS: NO COMPLETE SHIP SETS.
USS ABRAHAM LINCOLN (CVN-72) [PAC]
USS THEODORE ROOSEVELT (CVN-71) [LANT].
USS CARL VINSON (CVN-70) [PAC].
USS WASP (LHD-1) [LANT].
USS KEARSARGE (LHD-3) [LANT].

COST AVOIDANCE: $5.6M / 20-YEAR FROM FLEETWIDE USE OF 1.5” BALL VALVES USED IN SEAWATER PRESSURE REDUCING STATIONS.
$12.9M ANNUAL COST AVOIDANCE FROM COMPOSITE VALVES.

MAN-YEAR LABOR AVOIDANCE: 2.02 MAN-YEAR/YEAR FOR ALL 1.5 & 2” VALVES;
23.8 MAN-YEAR/YEAR FLEETWIDE.

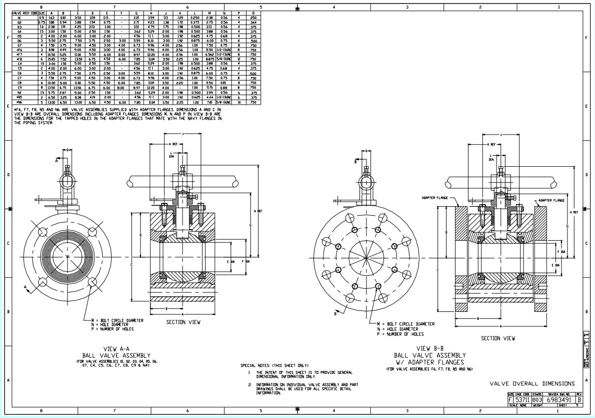
VALVES & VALVE PARTS

- NAVSEA Standard Drawing 803-6983491, Title: Marine Composite Ball Valve COMPLETE AND AT PORTSMOUTH FOR DISTRIBUTION.

- DRESSER CORP BUILT TOOLING FOR 4” FULL PORTED BALL VALVE FOR USE IN CHT DISCHARGE LINES. TOOLING COMPLETE 3 4-INCH VALVES TESTED AND INSTALLED. CURRENTLY THERE IS NO APL FOR 4-INCH TO 8 INCH COMPOSITE VALVES.

ADAPTATION OF 4” FULL PORT TOOLING TO PRODUCE STANDARD 6” BALL VALVE TO BE INSTALLED ON USS RONALD REAGAN

FY 04 DEVELOPING A 3-WAY 3-INCH CHT DIVERTER VALVE AT SSES (PHILLY) AND HARDENING EXISTING VALVES TO STAND UP TO HYDROBLAST CLEANING



4-INCH FULL PORT COMPOSITE BALL VALVE

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- COMPOSITE, 2” BALL VALVE IN LHD-1 PRESSURE REDUCING STATION.

- TRANSITION TOUGHENED ZIRCONIA (TTZ) SEAT RINGS REPLACED DAMAGED MONEL 400 IN 8 PRESSURE REGULATING VALVES ON USS ABRAHAM LINCOLN. EXPECTED LIFE EXTENDED FROM 1/2-YEAR TO 4-YEARS. 3-YEARS AND NO PROBLEMS WITH 8 VALVES ON USS ABRAHAM LINCOLN.

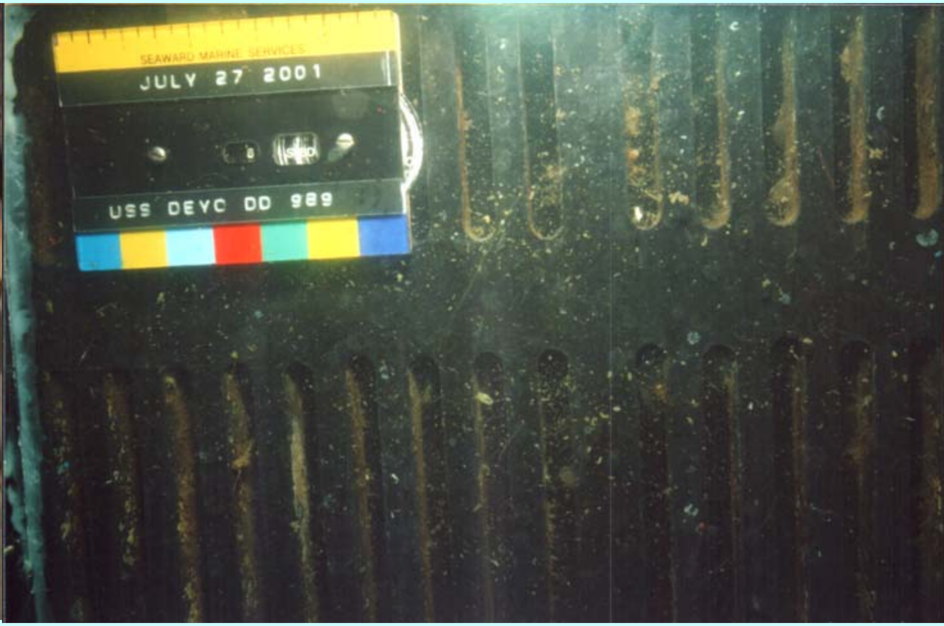
FUNDED FY 03-05 $175K/YR TO INSTALL TTZ SEATS ON NEW VALVE DESIGN AND PLACE IN SERVICE ON ALL CARRIERS

SEAWATER INTAKE SCREENS

CURRENTLY AN UNFUNDED PROGRAM

- PREVIOUSLY MADE BLENDING TBT INTO EPOXY AND E-GLASS NO LONGER VIABLE DUE TO NAVY, IMO AND EPA BAN ON TBT. INSTALLED ON DDG 80 AND USS MEMPHIS (SSN-688 CLASS SUB) FOR EVALUATION.
- SUCCESSFULLY POLYMERIZED NEWER, MORE ENVIRONMENTALLY BENIGN BIOCIDES (zinc and copper acrylate) WITH BOTH EPOXY AND VINYL ESTER RESINS. GOOD RESISTANCE TO BIOFOULING DEMONSTRATED THE PAST 2 SUMMERS IN CHESAPEAKE BAY

TBT SCREEN IN LAB



IN SERVICE AFTER 6 MONTHS

NAVSEA
NAVAL SEA SYSTEMS COMMAND

DMAG Joint Depot Maintenance Activities Group
Joint Solutions For Depot Maintenance

COMPOSITES IMMEDIATE AND FUTURE NEEDS

MIL-STD-2031(SH) FIRE REQUIREMENTS (needs revision)

- **Only 4 materials known that pass**
  - NRL - Phthalonitrile (~$600/lb)
  - EB – 2 Modified Phenolics
  - TRI - Modified Phenolic (~$15/lb)
    - **Passed cone calorimeter tests**
    - **Large scale tests in progress**
    - **Submarine mattress tray prototype**

Fire test/characteristics	Requirement	Test method
Oxygen-temperature index	Minimum	Appendix A
Percent oxygen at 25° C	35	
Percent oxygen at 75° C	30	
Percent oxygen at 300° C	21	
Flame spread (index)	Maximum 20	ASTM E 162
Ignitability (seconds)	Minimum	ASTM E 1354
100 kW/m^2 irradiance	60	
75 kW/m^2 irradiance	90	
50 kW/m^2 irradiance	150	
25 kW/m^2 irradiance	300	
Heat release (kW/m^2)	Maximum	ASTM E 1354
100 kW/m^2 irradiance		
Peak	150	
Average 300 seconds	120	
75 kW/m^2 irradiance		
Peak	100	
Average 300 seconds	100	
50 kW/m^2 irradiance		
Peak	65	
Average 300 seconds	50	
25 kW/m^2 irradiance		
Peak	50	
Average 300 seconds	50	
Smoke Obscuration Dmax occurrence	Maximum 200 seconds	ASTM E 662
Combustion gas generation	Maximum	ASTM E 1354
At 25 kW/m^2 irradiance		
CO	200 p/m[2]	
CO	4 percent by volume	
HCN	30 p/m	
HCL	100 p/m	
Burn-through fire test	No burn-through in 30 minutes	Appendix B
Quarter-scale fire test	No flashover in 10 minutes	Appendix C
Large scale open Environment test	Pass	Appendix D
Large scale pressurizable Fire test	Pass	Appendix E
N-Gas Model smoke Toxicity screening test	No deaths Pass	Appendix F

[1] Kilowatt per square meter (kW/m^2).
[2] Parts per million (p/m).

COMPOSITES
IMMEDIATE AND FUTURE NEEDS

Structogard® Installation on DDG Helo Hangar

COMPOSITES
IMMEDIATE AND FUTURE NEEDS

- “FIREPROOF” MATERIALS that meet MIL-STD-2031
  - Improved Strength
  - Improved Toughness
  - Low Water and Solvent Absorption
  - Low VOC
  - Economical
  - Easy Fabrication Techniques

- FINISHED PANEL FIRE INSULATION
  - People Friendly Installation
    (looks like an office, not a torture chamber)
  - Acoustic Properties
  - Easy to Clean
  - Easy Removal (hook & loop?)
    - Inspection Of Substrate
    - Lower Modification Cost

- DESIGN DATA SHEET
  - New Surface Ship Composite Structures Fire Performance Guidelines have been Issued by NAVSEA for DD(X) but are not yet written for American Bureau of Shipping Naval Vessel Rules.

CARBON FIBER

- Carbon fiber (graphite) is galvanically active
  - It reacts with metal – particularly aluminum
  - Corrosion degrades the laminate - corrosion salts grow on the carbon breaking the matrix
  - The yacht building industry (racing boats) learned how to handle this nearly 20 years ago
  - The aircraft industry still hasn't
    - Carbon must be completely isolated from metal
      - No metal fasteners used without isolating preferably with a non-metallic bushing
  - According to NAVSEA 05M2 (metals & welding) there are two very high strength alloys that will not react
    - MP 98T: 150-180 ksi and very expensive
    - MP 159: 200 ksi and even more expensive
  - Bonding is a viable alternative to mechanical fasteners
    - Many race boats are successfully bonded with no bolts

REPAIR NOTES

- **High tech composites can be repaired**
  - **Damaged area removed down to good laminate**
  - **Laminate must be dry (use a moisture meter)**
    - **Heat and vacuum-bagging will accelerate drying**
  - **Scarf ratio of 40:1 approaches original laminate strength**
  - **Scarf ratio of 12:1 is usually adequate for low tech laminates**
  - **Best repairs are infused and are <u>MUCH</u> stronger than hand lay-up**
  - **Scarfed surface must be abraded thoroughly**
    - **Seemann Composites lightly grit blasts & cleans**
  - **Polyester resin does NOT stick to Epoxy**
  - **Epoxy is repair resin of choice**
  - **Epoxy does stick to polyester and vinyl ester**